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THE FABRICATION OF PROTOTYPE NORMAL CONDUCTING REBUNCHER FOR THE MEBT IN RISP

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Abstract

The Medium Energy Beam Transport (MEBT) system of RAON consists of several quadrupole magnets for controlling the transverse beam parameter at the entrance of the low energy linac, three normal-conducting (NC) re-bunchers to match the longitudinal beam ellipse into the acceptance of the low energy linac and several diagnostic devices. The NC QWR re-buncher, which has a frequency of 81.25 MHz, a geometric beta factor of 0.032, and an effective length of 24 cm, has been fabricated and tested to demonstrate the frequency tuning by using slug tuner, power transmission and reflection with low input power, and pulsed high power transmission with cooling channels. In this presentation, we show the design and fabrication criteria for the high power, ~ 10 kW, re-buncher and its test results.

INTRODUCTION

The Medium Energy Beam Transport(MEBT) line system, which is located between the RFQ and the SCL, requires matching of the optical parameters in the transverse plane and removal of the unaccelerated ion beams from the RFQ. It also includes beam diagnostic devices to measure and control the beam quality and Twiss parameter at the entrance of the linac during a beam operation [1,2]. In our designed MEBT line, three normal-conducting re-bunchers with 81.25 MHz (β_g = 0.032) quarter wave resonators (QWRs) and eight room-temperature quadrupole magnets were chosen for the beam bunching, beam transport and matching. Strip-line beam position monitors, current monitors, a bunch length monitor, beam collimators and steering magnets are also installed in the MEBT line. The designed MEBT line can accept and control the transverse and the longitudinal distributions of several beams such as the 500 keV/u ^{238}U beam, the 500 keV proton beam, and the 500 keV/u ^{18}Ar beam [3].

ELECTROMAGNETIC AND MECHANICAL DESIGN

Two gap normal conducting 81.25 MHz quarter wave resonators (QWRs) were chosen to provide enough electric field for matching of the longitudinal phase space distribution from the RFQ into the linac [4]. The gap distance of the cavity is 5.9 cm that is consistent with the velocity of the ion beam. Based on the particle tracking simulation, the requirement of the peak electric field on the beam axis is about 3 MV/m to control the longitudinal phase space distribution and to remove the un-accelerated beams [5].

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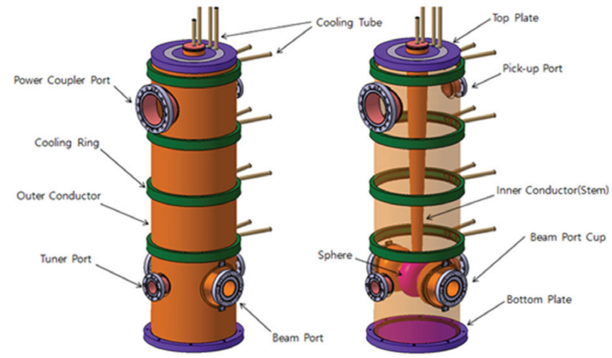

Figure 1: Drawing of the QWR cavity in MEBT of RAON.

As shown in Fig. 1, the bore radius of the beam pipe of the QWR cavity is 5 cm to minimize the uncontrolled beam loss. It was limited by the shunt impedance for getting a high acceleration field. The internal structure, such as shape of the stem, center sphere, and beam port, is optimized to decrease the surface electric field which strongly related with the heat loss from the QWR cavity. The electromagnetic design of the cavity is performed by using code CST-MWS and the electric field along the beam axis is shown in Fig. 2 [6].

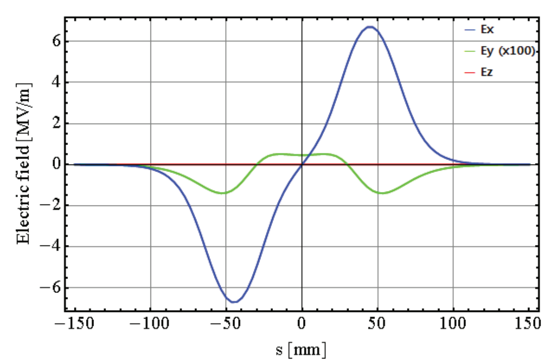

Figure 2: Electric field profile along the beam axis.

It has the electric field component on the vertical direction which can cause the orbit steering due to the structural asymmetry of the QWR cavity. The field strength, however, is small enough to ignore the orbit displacement at the entrance of the linac. It was confirmed by the tracking simulation.

The cooling of the QWR cavity is most significant factor for the mechanical design of the high power normal-conducting structure since the almost power, ~ 10 kW, is converted as the heat on the surface of the QWR cavity. The drawing for the cooling channels is shown in Fig. 3.

In order to suppress the heat up to 15 kW since the calculated power loss was to be about 10 kW for the electric field of 3 MV/m on the beam axis, the QWR cavity was produced

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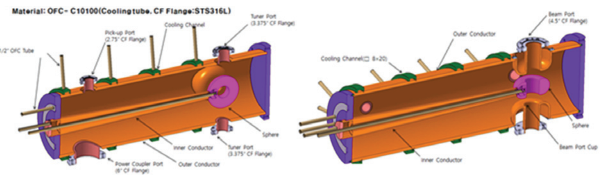

Figure 3: Drawing for the high pressure water cooling channels.

by the copper and it has five high pressure water cooling channel which is based on the media as the absorbing heat generated by a multitude of accelerator components for a few kW power.

FABRICATION AND TEST

The parts of the QWR cavity, such as top, bottom plate, outer conductor, beam port, inner conductor, and cooling channel, are fabricated by cutting and grinding the bulk OFC(Oxygen Free Copper) and the substances on surface were removed through a mechanical and chemical treatment. Before the brazing process to assembly the parts, the dimensions of each parts are measured by 3 D scanner to check the flatness and size of each components. The picture of the parts are shown in Fig. 4.

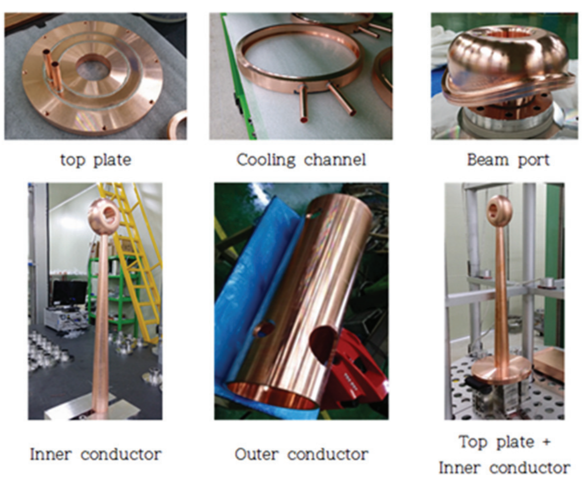

Figure 4: The picture of the parts of the QWR cavity.

The top plate was brazed with the cooling channel by using the BNI-2 material and the 1040 $°C$ condition is kept during 5 minute. For the inner conductor, the ^{35}Au-^{65}Cu material is used as the filler material and the 1035 $°C$ is kept during 5 minute. Especially, the BAg8 material is used as the filler material with 835 $°C$ condition for brazing the inner conductor with the top plate in order to prevent the distortion of the long stem. After finalize all process for combining the parts, the leakage is checked by using the He leak detector that is shown in Fig. 5.

In order to confirm the assembly status of the cooling channels, the leakage and high pressure of the cooling water is tested. The leakage of the cooling water is not observed

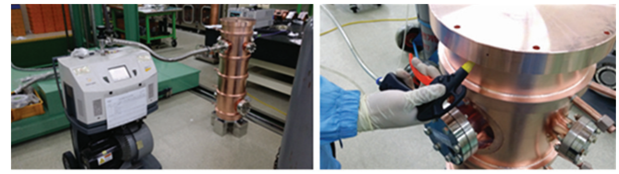

Figure 5: The picture of the leakage test by using He leak detector.

until 25 L/min which is higher value than the target pressure, 15 L/min. The test scheme is shown in Fig. 6.

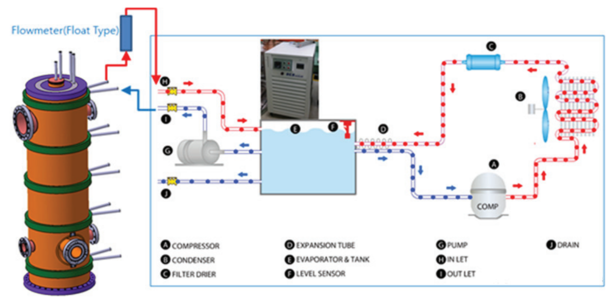

Figure 6: Schematic drawing of the cooling channel test.

The frequency shift due to the temperature variation of the cooling water is also measured to figure out the optimal temperature for the QWR operation that is shown in Fig. 7.

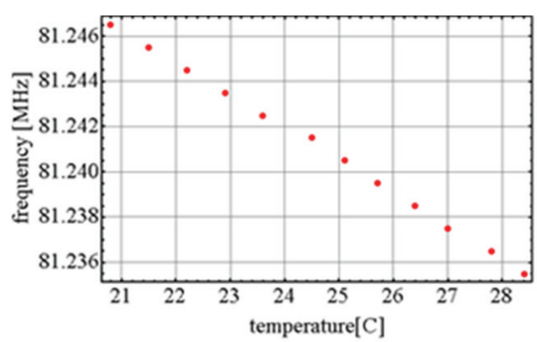

Figure 7: The measured resonance frequency as a temperature.

As shown in Fig. 7, the sensitivity of the cooling water temperature of the QWR cavity is 1.43 kHz/°C and the response is linear within the measured temperature range. Then the cooling water temperature, 27 °C, and the specification of the temperature fluctuation of the RCCS, less than 0.1 °C, is enough for the safety operation.

Even through the cooling water temperature is kept 27 °C, the resonance frequency of the QWR cavity is about 81.238 MHz. Then two slug tuners are installed to match the resonance frequency of the QWR cavity to be 81.25 MHz. Two slug tuners are installed in the perpendicular plane to the beam port which has the strong electric field. Then the resonance frequency of the QWR cavity becomes lower when the depth of the tuner is increased [7]. The

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sensitivity is calculated by the simulation using CST-MWS that is shown in Fig. 8.

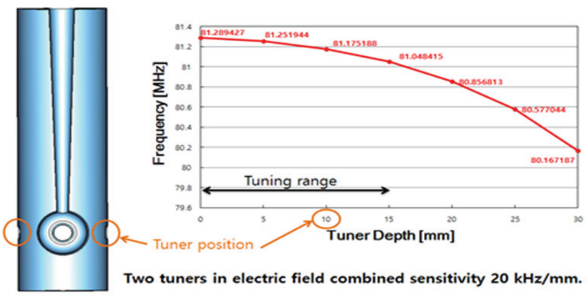

Figure 8: The calculated resonance frequency as a function of two tuners depth.

Based on the calculated result, the sensitivity of the resonance frequency as a function of the tuner depth is about 20 kHz/mm and the movable range of the tuner is set to be 15 mm with the original position of 10 mm. The measurement of the sensitivity of the resonance frequency as a function of two tuners depth is performed that is shown in Fig. 9.

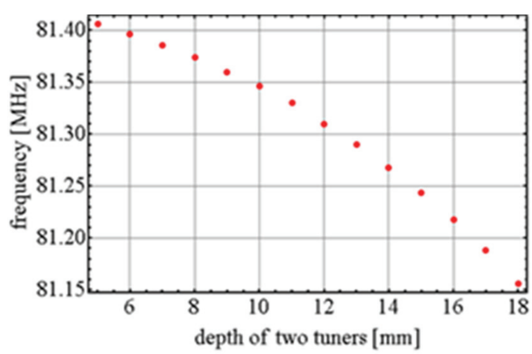

Figure 9: The measured resonance frequency as a function of two tuners depth.

The measured the sensitivity of the resonance frequency as a function of the tuner depth is also about 20 kHz/mm. The measured sensitivity agrees well with the calculated sensitivity. The tunable range of the resonance frequency using two tuners is from 81.4 MHz to 81.15 MHz. It is enough to compensate the variation of the resonance frequency due to the cooling water temperature variation. The depth of two tuners is set to be 15 mm to match the resonance frequency of the 81.25 MHz.

After tuning of the central frequency of the QWR cavity, the RF measurement by using the Vector Network Analyzer is performed. The central frequency, bandwidth, and external Q value are 81.25 MHz, 21 kHz, and 7738, respectively. The Return loss and coupling coefficient are -45.5 dB and 1.01, respectively. It agrees well with the designed values.

CONCLUSION

The electromagnetic and mechanical design of the normal conducting QWR cavity that has the resonance frequency of 81.25 MHz with the geometric beta, β_g, of 0.032, which is used for manipulating the longitudinal distribution of the beam at the entrance of the linac, is performed to optimize the structure in order to reduce the heat loss and to increase the field gradient at the gap. The designed QWR cavity has the four high pressure cooling water channels on the outer conductor and one high pressure cooling water channel at the stem to suppress the heat up to 15 kW. The vacuum and cooling water leakage test was done. The sensitivity of the resonance frequency as a function of the cooling water temperature and tuner depth are measured. It agrees well with the calculated values. The RF training and high power with lower duty will be performed this year.

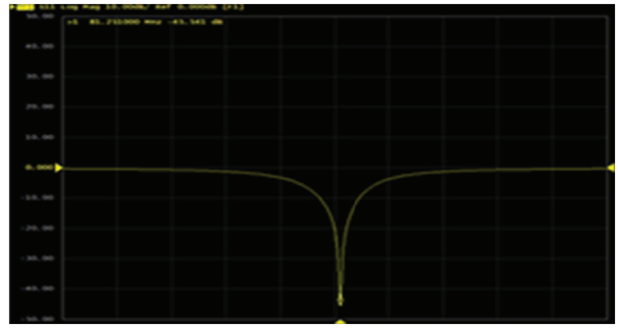

Figure 10: RF measurement by using the Vector Network Analyzer.

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